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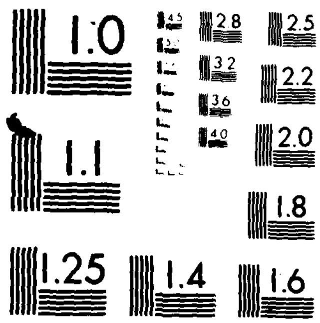

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LEVEL II

F-16 AIRCREW TRAINING DEVELOPMENT PROJECT

Contract No. F02604-79-C8875

RECOMMENDATIONS FOR F-16 OPERATIONAL FLIGHT TRAINER (OFT) DESIGN IMPROVEMENTS

DEVELOPMENT REPORT No. 22
MARCH 1981

Prepared in fulfillment of CDRL no. B041

by

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PREFACE

This report was created for the F-16 Aircrew Training Development Project contract no. F02604-79-C8875 for the Tactical Air Command to comply with the requirements of CDRL no. B041. The project entailed the design and development of an instructional system for the F-16 RTU and instructor pilots. During the course of the project, a series of development reports was issued describing processes and products. A list of those reports follows this page. The user is referred to Report No. 34, A Users Guide to the F-16 Training Development Reports, for an overview and explanation of the series, and Report No. 35, F-16 Final Report, for an overview of the Instructional System Development Project.

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F-16 AIRCREW TRAINING DEVELOPMENT PROJECT REPORTS

Copies of these reports may be obtained by writing the Defense Technical Information Center, Cameron Station, Alexandria, Virginia 22314. All reports were reviewed and updated in March 81.

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EXECUTIVE SUMMARY

Because the training development contractor has been involved early in the life cycle of the aircraft, the F-16 project provides an opportunity for instructional developers to provide input to the design of training devices to be developed for the F-16 training system. Some of the capabilities already incorporated in the design of the F-16 Operational Flight Trainer (OFT) such as freeze, performance replays, and automated measurement are highly desirable instructional features. In addition, it is recommended that capabilities be provided by grade sheet production, simulator setup and off-line debriefings, mission status and look-ahead, a self-instructional capability, and a "help" capability for instructors. Two problems with the physical arrangement of the OFT for training demonstrations were identified. A series of principles were specified for the formatting of instructional displays. A number of recommendations were made regarding the design of the OFT for simulating aircraft malfunctions. Finally, recommendations were made in terms of designing the OFT to accomodate growth and changes over the F-16 training system lifespan.

While the involvement of the ISD team in the simulator design process has been helpful in identifying design deficiencies, participation prior to simulator procurement in future projects would result in training devices which are more closely aligned to the requirements of the training system.

CONTENTS

RECOMMENDATIONS
FOR F-16 OPERATIONAL FLIGHT TRAINER (OFT)
DESIGN IMPROVEMENTS

1.0 INTRODUCTION

The F-16 Aircrew Training Development Project provides a unique opportunity for instructional developers to become involved in design of an aircrew training simulator for operational flight training. The long lead times required for the development of complex operational flight trainers (OFTs) and the customary late arrival of instructional developers upon the scene in an aircrew training system development usually prevents instructional scientists from applying the principles of instructional systems development (ISD) to such designs. As a result, the dominant practice has been to design simulators to meet standards of simulation fidelity rather than standards based upon training requirements.

In contrast to this normal state of affairs, the F-16 aircrew training development contractor has been involved earlier in the life cycle of the aircraft system, at a stage when many details of the F-16 OFT design are not yet firm. The unusual opportunity is presented to align, to the extent possible, simulator design characteristics (both physical and software) with the requirements of the instructional system developed for training F-16 pilots and instructor pilots.

The purpose of this paper is to recommend design features for the F-16 OFT which support training requirements of the F-16 instructional system. The cost/benefit tradeoffs prerequisite to the implementation of the suggested features have not been conducted. The suggestions presented here are based upon the ISD program design products, preliminary descriptions of the simulator design concept provided by the simulator contractor, and suggestions from the F-16 OTD team and other Tactical Air Command (TAC) agencies involved in simulator design, review and procurement. Proposals contained herein have been developed through preliminary design review meetings at the simulator contractor's facility, and through examination of fragmentary reports and preliminary specifications provided at that meeting. No systematic review of the completed design has been accomplished, and to the best of our knowledge, no thorough analytical determination of functional requirements for the F-16 OFT/WST (weapon system trainer) was undertaken prior to the commencement of design.

While the involvement of the ISD team in the simulator design review process has been helpful in identifying selected design deficiencies in relation to the functional objectives of the OFT, participation prior to simulator procurement specification in future projects will result in a more extensive and influential statement of design objectives. Ideally, the ISD effort should produce a set of training-task-based performance specifications which, taken together with the simulator concept of employment, including instructional strategies, would form the nucleus of future procurement specifications.

This fact notwithstanding, an attempt has been made to make recommendations in areas of the simulator design which directly relate to the application of instructional strategy or the operation of the simulator as a tool by simulator instructor pilots. It is the philosophy of ISD that the simulator is an instructional tool to be used by a training manager or an instructor for the purpose of meeting specific student needs as the student progresses toward the acquisition of identified psychomotor skills. Just as any tool meant to be used by a workman should be designed to meet the workman's need, the simulator should be designed for use by the instructor as an agent in producing specific behavioral changes in the student.

It is the principal concern of this report to advocate the application of ISD principles in the simulator design and to ensure that a proper perspective of the OFT as a training tool guides the design process.

Simulators are vastly complex devices, and to fully evaluate simulator designs requires breadth and depth of knowledge in several specialty areas. Certain aspects of the F-16 simulator design, particularly engineering features, are beyond competent comment by the authors. In general the recommendations do not extend to detailed hardware engineering that gives the machine its capabilities.

To organize the contents of this paper, recommendations are given under three main headings, dividing the study into sections on (1) instructor operator station interface design, (2) specific instructional capabilities, and (3) design for growth. Within each of these areas problems in the simulator design as presently conceived are identified, and recommendations are made aimed at solution.

2.0 SPECIFIC INSTRUCTIONAL CAPABILITIES

Characteristics of a simulator that transform it from a high-fidelity aircraft system mimic into a training device are its instructional features. These features allow the instructor to produce simulation exercises with the most appropriate blend of pauses, feedback, cueing, instructor-student interactions, instruction, and motivation.

Several useful instructional features are already incorporated into the F-16 OFT design including capabilities for freeze, replay of student performance, demonstrations, and automated performance measurement for simple performances.

This section discusses specific additional capabilities which will facilitate the instructor's role as a manager of simulator exercises.

2.1 Grade Sheet Production

Problem: The requirements for data for performance measurement have prompted a move in simulator design toward production of appropriate data outputs. The approach to creating these outputs, however, has often been to produce large volumes of data in the hope that within the data the instructor will be able to find some measures of personal usefulness. The resulting data outputs are generally excessively bulky and difficult for the instructor to use in a debriefing session immediately following the flight. Moreover, the largeness of the body of data produced encourages variations in interpretations of variables by different instructors. The absence of focus appears to encourage non-standardization of evaluation.

Recommendation: The F-16 OFT should produce carefully structured records of relevant data output in a format readily usable by instructors for debriefing and historical purposes. The emphasis in this recommendation is on the production of documentation from the simulator which can be effectively used by the instructor during the debriefing process, and which contains sufficient information that it be usable as a part of the student's grade record. An example of such a printout is presented in Figure 1. That figure represents a printout page as it might appear at the end of the takeoff and departure portion of a navigation exercise. The novel feature which distinguishes this page is that the end state of the mission segment is presented as well as the critical parameter values associated with the airplane's flight at earlier significant points in the mission. Comparison between these values and criterion values can be made easily for each point during the mission. The generation of these displays requires the simulator to freeze the desired data on aircraft flight performance on the page at appropriate locations as the flight progresses.

KEY:

1 AIRFIELD SYMBOL

2 DESIRED AIRCRAFT FLIGHT PATH (SOLID LINE)

3 AIRCRAFT ALTITUDE, AIRSPEED, HEADING AND TACAN POSITION DATA DEPOSITED ON SCREEN DURING EXERCISE

4 ACTUAL AIRCRAFT FLIGHT PATH (DOTTED LINE)

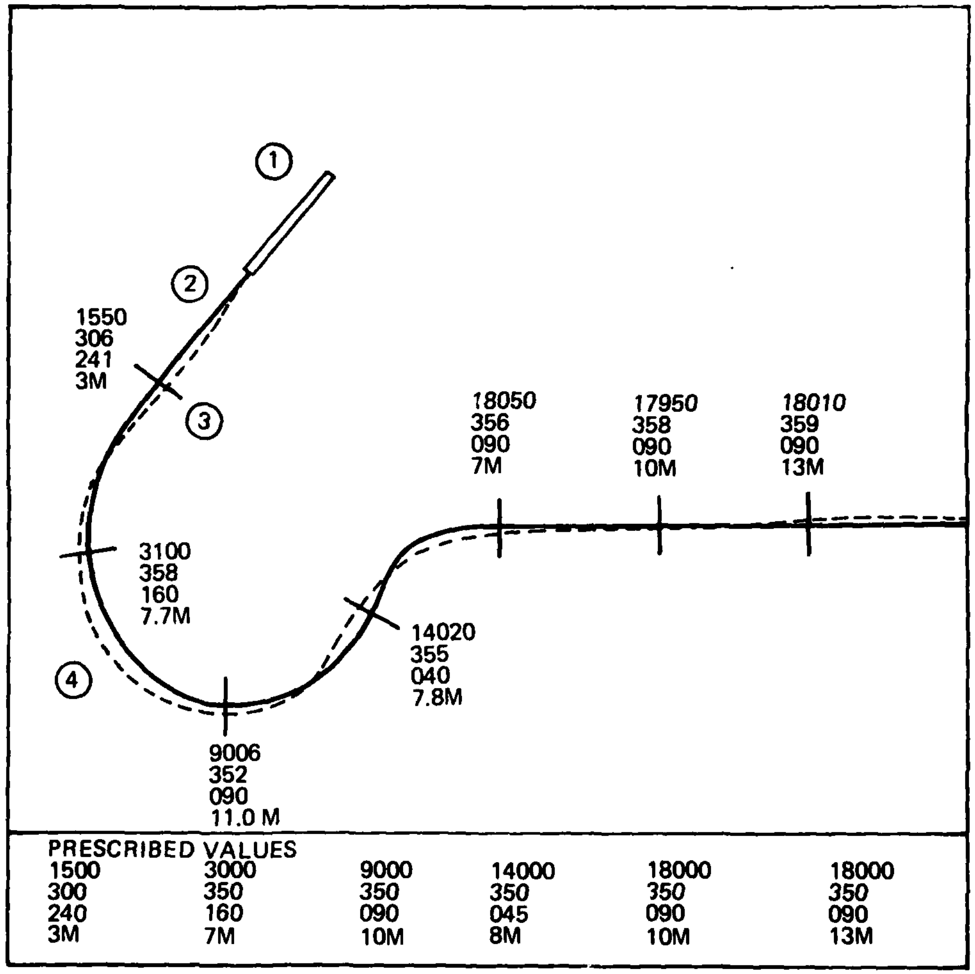

Figure 1 — A Sample Printout Following Simulator Use Suitable for Debriefing and Grading

It is believed that useful grade sheets could be produced for virtually all of the major training sequences carried out in the simulator, including air-to-air combat in advanced versions. Much thought and preparation, however, must go into the design both of the machines and of the printout formats to accomplish this objective.

2.2 Offline Problem Set-up/Debrief

Problem: Simulator instructional sessions are typically scheduled to last from 1-1/2 to 2 hours including time for simulator programming and student debriefing. If simulator programming and post-flight review become lengthy, the percentage of the scheduled session remaining for the actual simulated flight rapidly diminishes with consequent reduction in the time efficiency of simulator training. For example, if set-up takes 15 minutes of interaction with the instructor/operator station (IOS) console, and debrief involves 15 minutes of replay and discussion with the student, only 2/3 of the scheduled 1-1/2 hour period can be available for flight simulation. This level of utilization equates to a 50% increase in real simulator training time cost. Means must be sought to achieve the highest possible level of simulator utilization.

Recommendation: A capability should be established to perform simulator set-up and/or student debriefings off-line. If a means can be found to perform set-up and debriefing tasks concurrent with flight simulation operations, the utilization potential and operating costs per student training hour can be immediately improved. For mission set-up, an IOS "emulator" could be developed. This device might be a micro-computer based dynamic replica of a single IOS display station capable of presenting simulated "menus" of instructor options exactly as they appear on the IOS. Instructor selections on this IOS "emulator" would be either relayed into a buffer store in the simulator memory for retrieval at the start of the succeeding training period, or recorded onto some transportable media for physical relocation to and transcription by the simulator at that same time.

Off-line reconstruction of simulated flight events would involve somewhat more complex and expensive equipment; thus a careful determination must be made of the cost-effectiveness of this proposed feature. The potential benefits of an off-line debriefing capability are significant, however. Anticipated benefits of this arrangement are: (1) relief in the demand for the IOS at critical transition periods, (2) lower operating cost, (3) further offloaded demand for the IOS if the debrief capability is designed to incorporate snapshot production, (4) automated performance analysis capabilities, and (5) elimination of time stress that often detrimentally influences the review process.

It is elsewhere suggested that consideration be given to designing air combat manuevering range (ACMR) replay compati-

bility into the F-16 OFT. (See Section 4.2 of this report.) It would be desirable if this feature were incorporated in any debriefing device like the one described above. Instructors would have more frequent opportunities to use the simulator equipment in this event, which would equate to greater confidence and skill in utilization of the simulator equipment itself. This feature would also help to amortize costs over a greater usage base and thus lower operating expense still further.

2.3 Mission Status and Look Ahead

Problem: During the course of a simulation exercise, planned and unplanned events occur in which the instructor must participate, either as a source of information for the student, or as a problem controller by interacting with the IOS controls and displays. The instructor must not only be fully aware of events which have already transpired in an exercise and student performance during each, but must be able to look ahead and anticipate coming events, both planned and random so that he may carry out his responsibilities. The demands on an instructor's time while managing a simulation exercise are great, and the requirement to anticipate upcoming events while managing ongoing ones is an added burden which can be avoided. To alleviate the memory burden for instructors, and to make preparation for both expected and random events less demanding of attention, a cueing mechanism for alerting the instructor of upcoming events will be helpful.

Recommendation: <u>It is recommended that a feature be provided allowing the instructor pilot (IP) to examine the profile of a training mission (past and future) while the mission is being conducted, and determine the progress through the mission to that point while being alerted to the nature and time of occurrence of events yet to transpire during the mission</u>. This feature may take one of two forms. Either it may be a feature separate from the problem pages, or it may be implemented as a simple overlay imposed upon the screen while an instructor is yet monitoring a given training problem in the form of leading logic for instructor actions. The look-ahead capability should also assist the IP in avoiding violation of the simulator operational parameter range limits by indicating threats that could terminate the mission, by warning the IP of pending automatically inserted malfunctions (Section 3.6), and by alerting the IP of upcoming responsibilities, including radio calls and clearances. In this connection, it is suggested that such leading logic take the form of a flashing message on the IOS displays requiring an acknowledge button activation to stop the flashing. This status and look ahead capability could also monitor and alert the IP to the possibility of selection of incompatible or catastrophic combinations of parameters.

3.0 INSTRUCTOR/OPERATOR STATION INTERFACE DESIGN

The F-16 OFT design must insure that the physical layout and mechanical and functional operation requirements of the simulator do not interfere with its use as a training tool. This section contains recommendations for design improvements to promote an instructor-job compatible OFT.

3.1 Self Instructional Feature

Problems: There is a need for training OFT instructors to use the simulator. Two problems exist.

1. The flexibility provided by modern flight simulators requires that the operator make many choices in selecting desired operating conditions. Mastery of simulator control implies training in option selection and operation of the simulator interface, which quickly becomes more than a trivial training problem.

2. Dedicated simulator operation personnel are not employed, and training, though often implemented as part of the qualification for instructors, is not maximally effective. USAF simulators use frequently-rotated personnel as instructors, who in addition are often assigned additional duties and instruct on the simulator equipment infrequently. In this situation, extensive training is impractical and not likely to be well-retained. Consequently simulators are not used to full efficiency or capability.

Recommendation #1: <u>The simulator should incorporate a self-instructional feature for IPs that operates through on-simulator tutorials</u>. A self-instructional capability could be produced to be implemented either at the main instructor console or at an isolated console (Section 2.2) while the simulator is running instructional problems. The memory and central processing unit (CPU) load required by instructional delivery by computer is relatively low, and it is highly likely that sufficient time will exist within the operating system of the simulator to service an instructional program at the same time a simulation problem is being run. This will be especially true if other recommendations of this report concerning reserve computational power are implemented. (See Section 4.6.)

Recommendation #2: <u>It is recommended that a "HELP" function be available to IPs while using the simulator for the purpose of guiding or suggesting instructor actions/options at points where the instructor recognizes that he does not understand what options are available</u>. This "HELP" function could summon to the display specific computer recommendations for control action associated with the current state of the simulator, or at very

least a map or menu of options open to the instructor at a given time.

3.2 Mockup Physical Arrangement (I)

Problem: Since the operators will be looking up at the midpoint of the cathode ray tube (CRT) displays, and since the front surface of such displays typically reflect specularly with high efficiency, the potential for nuisance reflection of room lights above and behind the operator is quite high. While the annoyance created by these reflections could be eliminated by careful placement of the room lighting, such a constraint is inconsistent with USAF facilities plans.

Recommendation: Two minor modifications to the IOS will be helpful in minimizing the problem. First, consideration should be given to tilting the CRT's forward. Such an inclination would lessen the probability that specular reflections of the overhead lights could reach the operator's eye. A second solution would be to use either neutral density or matched spectral filtration on the CRT faceplates. Filtration would attenuate reflected room light by a factor equal to the square of the filter transmission percentage, because the incident light would have to pass through the filter twice. Light from the CRT phosphor would pass through the filter only once, and although the overall brightness of the CRT displayed information would be diminished, the contrast would be improved.

3.3 Mockup Physical Arrangement (II)

Problem: Review of the physical configuration of the IOS revealed a potential problem in that the small radius of the curved work surface severely limits the size of the observer's viewing space. In situations where additional personnel, whether operators or observers, are attempting to simultaneously observe the IOS display console, unacceptable crowding is probable. This is especially likely to occur during transitions between simulator training sessions when one instructor and student are debriefing while a new instructor and student await an opportunity to program the simulator for the succeeding lesson. Expanding the size of the IOS may be unacceptable from the standpoint of operating efficiency, as well as the consequent need for additional space in the simulator facility.

Recommendation: No solution to this problem is immediately apparent. The contractor might consider other form factors for the IOS which provide a greater viewing volume for the displays yet do not increase the physical spacing between them. Clearly additional study is required.

Note: One possibility which should be considered is a remote debrief or lesson programming station which would minimize simultaneous demand for the IOS. This suggestion has already been discussed in detail. (See Section 2.2.)

3.4 Instructor Displays of Student Controls

Problem: Though present F-16 OFT plans include instructor displays of instrument readings and major control settings, during instrument failure for the student it is also planned that the instrument reading will fail also for the instructor. This will render the instructor incapable of determining the status of the student's aircraft.

Recommendation: The instructor display of student indica-- tors and controls should show appropriate readings continually rather than as a function of student views.

3.5 Page Format

Problem: Simulator CRT pages are the principal means of communication of both situational and control data from the simulator to the instructor/operator. As potential bottlenecks in the closed-loop information flow between machine and operator, the capacity of the CRT pages to present information and the capacity of the operator to perceive and interpret it may jointly limit the information transmission rate around the loop. The quantity and quality of information exchanged through this channel is a prime measure of the effectiveness of the IOS and consequently of the entire OFT as a training tool. All too frequently inadequate attention is paid to structuring information on CRT pages in a way that makes the nature of the information clear and the exact values quickly readable and easy to locate. Also ignored in CRT page construction are the perceptual preferences of the user. What may be most convenient to display from a data processing standpoint may not be the most interpretable form. For example, easy to use symbolic or pictorial representations are often avoided in favor of easily programmed lists and tables.

Recommendation: The F-16 OFT IOS display will, upon demand, present nearly 250 pages of data to the instructor for his use in monitoring and controlling simulator exercises. An extensive study of instructor/operator information needs and problem structures, combined with known principles of efficient display arrangement would no doubt lead to a set of optimally-configured display formats. While the value of such a study would have high payoff in increased instructor performance, particularly at this stage of OFT design, the necessary resources in time and money are not available to the F-16 ISD effort.

In lieu of that study the following principles and examples are offered as guidelines in the design of F-16 OFT CRT page

formats. These principles have been found through empirical study to create displays which promote efficient communication of information to human machine operators. The organization of information for interpretability and the perceptual requirements of the human operators have been taken into account in these principles.

Principle #1: The design of a particular page must be made with an understanding of the use an operator will make of the information on the page. On the F-16 IOS display CRT pages are used for three principal functions: (1) to provide feedback on performance of the student on a simulated task, (2) to control the task structure given to the student, and (3) to control the operational state of the simulator. This information is put to various uses by the instructor. Some of it is used in highly time-constrained decisions processes, some is used for purposes which require a high degree of accuracy, and in other situations the absolute value of a parameter is not as important as the direction or rate of change of a parameter.

Imagination must be used in the creation of display formats appropriate to each of these uses. For instance, an item of information which must be quickly read with moderate precision may be shown in pictorial form, whereas a slowly changing parameter which must be read with great precision must be presented in the form of a numerical read-out. Numerical readouts are not as effective as indicators of rate and trend information nor are pictorial representations, so a different solution must be found for displaying these data. A thermometer-like analog read-out could show both momentary value and rate of change for these data.

Principle #2: Information displays used only occasionally must be encoded in a form as closely as possible resembling the observer's natural pictorial and verbal language. Any device with the complexity of the F-16 OFT necessarily imposes a heavy training burden on its operators. Remembering where within the 250 CRT pages an item of information is presented may present an insurmountable problem to the casual user. The problem is compounded if the user must also learn non-symbolic codes to access or change data. Research on display design has demonstrated that this burden can be significantly lightened by maximizing the correspondence between display format and intuitive expectation. The use of English phrases and pictorial graphics in place of abstract codes are practices which promote and refresh familiarity with information identity. Placing information in geometric context in accordance with stereotypical expectation has also been found to help reduce access time and promote memory for information location. The application of these principles is difficult to generalize but is largely a matter of common sense.

Principle #3: Where quick acquisition of displayed information is required by the demands of the application, the amount of information on the display must be limited relative to its abso-

lute capacity for presentation. When time is a factor, care should be exercised to take advantage of decoding and formatting tricks which have been found to provide more rapid access to data. Among these techniques are the following:

1. Displays should be simplified to contain only essential information. It is very difficult to extract a particular item of information from a saturated display, for example, to find a number in a column or to find a keyword in a page of closely-packed text.

2. Information should be organized into related chunks so that the discrimination task becomes one of searching for a class of items rather than an individual item. These classes of information may be discriminated from each other by physical location encoding or by setting off an entire category by enclosing it in a box (with a label at the head of the box).

3. Redundant coding should be used. The indication of critical attention-demanding items by flash-coding or color-coding and the indication of parameters which can be changed as opposed to parameters for informational purposes as differences in type face or display intensity or denotative symbols such as underline.

Principle #4: Organize CRT page structure along logical lines. When in any hierarchical system of CRT pages the problem of navigation through the structure of the page arises, frustration to occasional system users will be met. Some suggestions for avoiding losing instructors/operators in the page maze follow:

1. Use road signs and road maps. Each page must have a title which conveys its logical relationship to pages higher and lower in the organizational scheme.

2. Provide access to orienting information. A "Where am I?" function which calls the roadmap to the display with a "you are here" indication and information on how to transfer to other locations is recommended. This page should be accessible to the user by a single control function. Return to the original point of inquiry should also be a single control function.

3. Trade breadth for depth. CRT page structure should avoid being many pages deep in favor of being many pages wide.

4. Simplify page transition from any given page to any other by designating the title of the destination page. While the traditional up-down flow through hierarchy of pages is useful in some situations and should be preserved, the direct transition capability will greatly simplify simulator operation and reduce the memory burden for occasional operators.

Principle #5: The psychophysical properties of the CRT display should be appropriate to the simulator operating environment. The IOS design engineering effort must include analytical consideration of the contrast, brightness, and surrounding ambient illumination level for the IOS display to insure that adequate viewability of the displayed information is obtained. In addition, factors unique to specific operating environments must be considered for their effect on display interpretability.

While there are design features which may deal with distracting factors, all cannot be anticipated, and consideration must be given to the selection of display characteristics which minimize the impact of these factors. For example, the use of color coding or flash coding is of questionable value in an environment filled with flashing colored lights which may reflect off the screen.

3.6 Automatic Malfunctions Indication

Problem:

1. The F-16 OFT will have the capability to introduce randomly selected malfunctions to the simulated scenario, either as part of an automatic malfunction generation sequence, or as a consequence of simulated battle damage.

2. When malfunctions are manually inserted by the instructor, he may anticipate the upcoming event and be prepared to note appropriate student response to the situation.

3. When these malfunctions appear unannounced, however, the instructor is likely to be as surprised as his student and may be unable to monitor the student's response in the desired fashion.

Recommendation: The F-16 simulator should provide the instructor with advance indications of the nature and time of occurrence of automatically inserted malfunctions. Warning indications should appear sufficiently early so that the instructor can take action to modify or inhibit the scheduled event if desired. Instructor concurrence with automatically selected events is not required, but an injunction against the automatic action should be easy to obtain by simple control action to extend the instructor response time available.

3.7 Malfunction Codes

Problem: Present F-16 OFT plans call for the selection and indication of malfunction options using numerical codes. These numeric codes, one for each malfunction, convey no semantic

information about the real name of the malfunction and have to be memorized by instructors by rote. Individual instructors using the simulator constantly might be expected to memorize these codes to the level of usefulness. In common experience, however, individual instructors do not get frequent enough exposure to the simulator to retain an adequate degree of familiarity with such symbols. As a consequence, it is entirely predictable that if no better device for symbolism is created the F-16 simulator IOS will be wallpapered with crib-sheets. The constant reference to these will interrupt the smooth and efficient flow of IOS operation. Worse, important mission events may escape the instructor's notice while he searches for the appropriate numerical codes.

Recommendation: Simulator designers should establish a list of commonly used terms and denote aircraft system events with mnemonic codes for those terms. Certainly, mnemonic codes could be used to indicate active malfuctions on non-interactive displays with very little design impact. Furthermore, mnemonic codes could also be associated with numerical codes on selection menus to clarify instructor options. Optimally, reference to options would be manipulated by instructors using these mnemonics rather than meaningless numerical codes. However, it is recognized that major IOS design impact would be incurred by this arrangement. Because of the familiarity and meaningfulness of these mnemonic terms both within the context of IOS usage and from acquired significance through common usage, instructors would find the interpretation of IOS displays to be much more quickly learned and more easily retained.

3.8 Catastrophic Malfunction Combinations

Problem: Certain combinations of selectable malfunctions may preclude successful completion of the simulated mission either by elimination of essential capabilities, or by rendering the simulated aircraft impossible to control. While under calm circumstances the instructor will anticipate the consequences of manually inserted malfunctions, this may not be easily possible when the instructor's workload is increased by tactical management responsibilities, communications, performance monitoring, flight profile amendment actions, etc. In such stressful instances, the instructional schedule or instructor whim may stimulate the insertion of an individually benign but combinatorially catastrophic malfunction.

Recommendation: Logic should be built into the IOS software complement to provide the instructor with warning that emergency combinations will be counterproductive to the objectives of the selected mission. While the logic should stop short of inhibiting an instructor action, advance indication of possible lethal combinations of selectable events should be provided. At a minimum, a challenge/confirmation interchange should be initiated by manual selection of such incompatible combinations of events.

4.0 DESIGN FOR GROWTH

Through the service life of the F-16, changes can be expected in the airframe and avionics which will impact the instructional system design and the configuration of the F-16 OFT weapons system trainer (WST). In addition, during the lifetime of the simulator, advances in the technology of simulator instruction will also suggest changes to enhance the OFT's effectiveness as an instructional tool. The simulator design must be sufficiently flexible that, as these changes create new requirements for simulation capability, they can be met with minimum impact on the system hardware. Such flexibility is obtainable, but only if set out as a design objective early in simulator development.

4.1 Design for Expansion (I)

Problem: The F-16 OFT is being procured with a number of options under consideration for later addition. Among these options are computer-generated visual scene simulation, performance measurement capability, adaptive training logic, and automated training capability. These additions may take the form of increments to the simulator software ensemble if sufficient computational reserve is available within the basic simulator system. (NOTE: It is a common temptation to size computational capabilities as closely as possible to the current need, ignoring likely future demands for additional capability. This should be avoided in the F-16 simulator.)

In all likelihood, one or more of the additional features projected for the F-16 simulator will require additional hardware to be added to the basic simulator, and will in addition require the transferral or exchange of a large volume of data at high speed between the presently planned and add-on data processing equipment. Since the simulator must perform in real-time, there can be no tolerance for interrupts to service these data requests. Some means other than disrupting the flow of the mainline simulation software must be found to provide the required data intercommunication capability.

Recommendation: <u>A dual-port common data pool memory should service the simulator while simultaneously providing access to important parameters in memory for add-on functions.</u> If such a solution is not possible, care will have to be taken to ensure that sufficient CPU speed is available to conduct the primary simulation function while simultaneously servicing interrupts associated with the various add-on options. While such a design practice might seem obvious, provision of reserve speed will necessarily involve increased cost. Compromise for cost savings purposes must not be made at the risk of incompatibility with intended add-on options.

4.2 Design for Expansion (II)

Problem: Two training environments will be employed for instruction in skills associated with air combat maneuvering (ACM) operations in the F-16. One of these, of course, is the aircraft. ACM missions will be practiced under relatively uncontrolled conditions in restricted airspace reservations, and under close scrutiny but still relatively uncontrolled conditions within the confines of ACMR instrumented facilities. The latter are capable of recording key details of missions for later replay and review. The second training environment for the introduction of ACM skills is scheduled to be the fully expanded WST version of the F-16 flight simulator. There, conditions can be highly controlled, but will be of questionable realism due to unavoidable fidelity shortfalls. It may be highly advantageous to devise a mixed media approach to instruction in ACM skills that exploits the realism of the ACMR environment while capitalizing upon the control afforded by the F-16 WST. One such strategy that might be considered would be to use the WST to review and repeat ACMR flown exercises in the simulator.

Recommendation: Provide software in the F-16 OFT/WST to interpret and reconstruct missions flown on the ACMR using range tapes produced by Cubic Corporation equipment as input media. This capability should enable the instructor to stop action or designate any point in the ACMR record as an initial condition set for beginning an autonomous exercise in the OFT/WST.